AN NxM OPTICAL SWITCH HAVING A SIMPLIFIED ALIGNMENT MEANS

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to an optical switch wherein optical waveguides are positioned at a focus of a reflector, and a refractive element pivots in the switch for optically coupling different sets of the optical waveguides.

Description of the Prior Art

U.S. Pat. No. 5,361,315 discloses an optical switch comprising: a refractive element between a reflector and multiple optical waveguides, the refractive element being pivotable to a first position to optically couple a first set of the waveguides, and the refractive element being pivotable to a second position to optically couple a second set of the waveguides. Each set of waveguides is optically coupled by light being transmitted from one waveguide of the set to another waveguide of the set. This patent recognized that the waveguides are required to be positioned at a desired focus from the reflector. However, the reflector is mounted on the free end of a pedestal and is subject to misalignment from abuse or temperature changes.

U.S. Pat. No. 5,661,827 discloses an optical switch which comprises, a refractive element between a reflector and multiple optical waveguides, the refractive element being pivotable to different positions to optically couple different sets of the waveguides, the reflector being received on a reflector holder, the reflector holder engaging spaced apart springs, and the

springs being compressed to aim the focal point of the reflector at a precise position in front of the waveguides. An advantage resides in the focus of the reflector being adjustable to a desired position in front of the waveguides. One feature of this invention is the dome shaped springs that are compressed by the reflector holder. The springs are said to provide the advantage of being compressed by the reflector holder to aim the focus of the reflector. Another feature of this invention is said to be the adjustment screws that engage the reflector holder and cause compression of the springs to aim the focus of the reflector. However, the dome shaped springs can be very sensitive in the alignment phase and can be adversely effected by rough handling and temperature changes. The sensitive of the dome springs during the alignment phase can greatly increase the alignment effort. This is especially true for single mode waveguides.

One feature of the present invention is the provision of a reflector secured in a fixed position at one end of an elongated chamber which also contains a waveguide array.

Another feature of the invention is the simplified alignment procedure which permits both preliminary visual alignment of the optical elements and fine instrument alignment of the optical elements.

Other advantages of the invention will be appreciated by those skilled in the art based upon the disclosure set forth herein after.

SUMMARY OF THE INVENTION

The present invention provides an optical switch which

includes an elongated chamber having a reflector end where a reflector is held in a fixed position and an array end where a waveguide array is held in a fixed position at a selected distance from the reflector. The chamber includes an aperture located between the reflector and array ends and dimensioned to permit the passage of a refractive element, having parallel major surfaces, into the chamber in a location that is between the fixed reflector and the fixed array. The refractive element may be placed at a plurality of angular positions to selectively couple an input waveguide with an output waveguide by rotating the reflective element about an axis parallel to its major surfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described with reference to the following drawings wherein like numerals refer to like elements throughout.

Figure 1 is an optical schematic representation of the rays in a switch according to the invention with the refractive element in a first angular position.

Figure 2 is an optical schematic representation of the rays in a switch according to the invention with the refractive element in a second angular position.

Figure 3 is a perspective view illustrating a precision fiber aliner useful with the present invention.

Figure 4 is a perspective view of a partially assembled optical switch incorporating the features of the present invention. **Figure 5** is a section through the line 5-5 of

Figure 4.

Figure 6 is an illustrative view of the reflector and waveguide array assembled in a chamber according to the present invention.

Figure 7 is a simplified exploded view of the chamber and cradle portions of the present invention.

Figure 8 is an illustrative, exploded view of a simplified chamber and cradle assembly with a base according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In principle, the operation of the optical switch of the present invention is based on Snell's Law of Refraction and the reflection characteristics of spherical mirrors. As most easily observed in the ray tracings of **Figures 1** and **2**, an optical signal, illustrated by rays **1** and **2**, enters the switch from one of the N number of input waveguides located in an array of optical waveguides **9** that includes the input waveguide **10** and two of the M number of output waveguides, here illustrated as first and second output waveguides **12** and **13**. The signal **1, 2** passes through a medium of refractive index R_1, air for example, located between the waveguides and a refractive element **6**. The signal **1, 2** is incident upon a first planar surface **7** of refractive element **6** that has a refractive index R_2, which is not equal to R_1. The signal **1, 2** then propagates through the refractive element **6** and exits through a second planar surface **8** into the medium between the refractive element **6** and a concave reflector **5**. This medium will typically be the same as R_1 on the waveguide

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side of the refractive element. The signal **1, 2** passes through this medium and is incident upon the reflecting surface **5**, where it is reflected back as illustrated by rays **3, 4**, to the refractive element **6**. The reflected signal **3, 4** is then incident upon the second surface **8** of the refractive element **6** and propagates through the element **6** until it exits from the first surface **7** where it propagates through the medium on the waveguide side of the refractive element **6** into one of the M output waveguides, illustrated as **12, 13**.

If the refractive element has two parallel surfaces **7, 8** through which the signal **1, 2** an **3, 4** passes, such as a plate of glass, the effect of the refractive element **6** when set at an angle alpha (corresponding to the angular position in Figure 1) or an angle beta (corresponding to the angular position in Figure 2) to the incident signal is to offset the reflected signal **3, 4** from the input signal **1, 2** by an amount d or d'. The amount of offset d or d^1 is controlled by altering the angle α or β of the refractive element **6** relative to the incoming signal. This enables the input signal N to be switched among the M output waveguides.

The simplest embodiment of the switch of the present invention is a one-in-by-two-out (nXm=1X2) optical switch. In alternative embodiments, the switch can have a larger number of inputs and/or larger number of output waveguides. The switches of the alternative embodiments would also include additional refractive elements. In general, the number of outputs is determined by the number of refractive elements. The possible number of outputs for such a switch can be defined by nXm^e where

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e is the number of refractive elements. For a switch with an exponent of 2, there will be four outputs; where e is 3 there will be eight outputs. It will be recognized that as more refractive elements are added the focal length between the waveguide array **9** and the concave reflector **5** will increase. This increase in focal length is accommodated by increasing the radius of the reflector **5** while maintaining the same rate of curvature. It will also be recognized that means for controlling the angle of each refractive element **6** will be required.

With reference to **Figure 3**, it can be seen that the waveguides **9** are mounted on the grooved plate **11** which has a plurality of channels **14** which are arranged to form the converging waveguide array **9** which positions the N input waveguide **10** with the M output waveguides **12** and **13**. This type of precision fiber aligning is described in more detail in U.S. Patent 5,361,315 which is incorporated herein as if fully set forth.

With reference to **Figure 4**, there is shown a partially assembled optical switch in accordance with the present invention, selected elements are not illustrated for the purpose of clarity. The switch assembly **20** includes a switch base **22**, a refractive element carrier **24**, a coil **28**, and the chamber **60**. The base **22** of switch assembly **20** includes a refractive element carrier **32**, positioned on one longitudinal side of the base **22**, that includes a generally U-shaped cavity **35** and an opposed refractive element carrier **34** on the opposite longitudinal side without the cavity **35**. The ~~reflective~~ refractive element carrier **24** is lgl carried by jeweled pivot pins which are inserted through the

egl apertures **36**. The ~~reflective~~ refractive element carrier **24** includes magnets **26** which come under the influence of coil **28** when it is activated. Although not shown for the purpose of clarity, a second coil **28** would be disposed in the cavity opposite the illustrated coil **28** to similarly influence the magnets 26. On egl the side opposite the magnets **26**, the ~~reflective~~ refractive element carrier **24** has an arm **25** which projects into the U-shaped cavity **35** of carrier support **32**. The position of the arm **25** of ~~reflective~~ refractive egl element carrier **24** within that U-shaped cavity **35** is determined by the position of stops located in aperture **33**. The use of pivotal refractive elements that are controlled through the use of coils will be known to those skilled in the art and is more fully described in U.S. Patent No. 5,661,827 which is incorporated herein as if fully set forth.

The relationship of the reflector **5**, refractive element **6** and the waveguides **9** is more easily seen with reference to **Figure 5** which is an illustrative section along the line of 5-5 of **Figure 4**. In the preferred embodiment, chamber **60** is cylindrical. It is believed that a cylindrical shape simplifies the structure necessary to provide the adjustments which will be described in more detail hereinafter. However, non-cylindrical shapes may be used so long as they are provided with a means for achieving rotation of the reflector 5 and waveguide array **9** relative to the refractive element **6**. Referring again to **Figure 5**, the reflector **5** is mounted on a reflector holder **80** which is positioned within the reflector assembly seat **82** of chamber **60**. Seat **82** is dimensioned to position the reflector **5** at a preset distance with respect to a perpendicular centerline through the

refractive element **6**. The reflector holder **80** is held in position by a threaded barrel lock **86** which is secured in the threaded bore **84**. As a result of this construction technique, the reflector **5** is placed in a fixed position at the reflector end **62** of the chamber **60**. At the opposite end of the chamber **60**, the optical waveguides are held in a fixed position at the array end **64** of the chamber **60**. Since the plate **11** of the array is generally flat, it is affixed to an array mount **66** which will complement the interior curvature of the chamber **60** and permit attachment of the array mount **66** to the chamber **60**, see **Figure 6**, with the waveguides vertically aligned. Mounting techniques suitable for use with array mount **66** of the present invention are described in U.S. Patent Nos. 5,361,315 and 5,661,827 as identified previously. Still with reference to **Figure 5**, it can be seen that the chamber **60** includes an aperture **74** which overlies the refractive element **6** which is mounted on the refractive element carrier **24**. Refractive element **6** is positioned between reflector **5** and waveguide array **9**. Chamber **60** also includes an angular viewing port **72** which is generally opposite to and centered over the aperture **74**. In the preferred embodiment, viewing port **72** is angled to permit a visual inspection of the input and output waveguides for reasons which will be explained further hereinafter. It can bee seen from **Figure 5** that the chamber **60** overlies the refractive element **6** but is independent of it. The assembly of chamber **60** will be described in more detail with reference to **Figures 7** and **8** hereinafter.

The chamber **60**, in its assembled form, is shown in **Figure**

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6 with chamber **60** shown in phantom to illustrate the internal positioning. As can been seen from **Figure 6**, the array mount **66** is mounted to the side of the chamber **60** with the array **9** in about the center of the chamber **60**. The mount **66** may be adjusted longitudinally in chamber **60**. This adjustment is accomplished by a hidden threaded bore **70** in the mount **66**. By attaching a threaded rod to the bore **70**, a technician may move the mount **66** longitudinally within the chamber **60** to achieve a desired position. The mount **66** may then be held in a chosen position with the fastener **68**. Since the interior diameter of the chamber is known and the center focal point of the reflector **5** is also known, it is possible through precision manufacturing of the mount **66** and the plate **11** to make an initial assembly which axially aligns the central waveguide on the Z axis with the reflector **5**.

The assembly of the switch base **22**, cradle **40** and chamber **60** will be described with reference to **Figures 7** and **8**. The chamber **60** of **Figure 7** is essentially identical to that shown in **Figure 6**, however, **Figure 7** includes the pin **78** in the aperture **76**. Pin **78** fits within the aperture **44** of the cradle **40**. Pin **78** provides a pivot point during alignment of the chamber **60** on the cradle **40**. Pin **78** is spaced from the slotted aperture **74** by a distance which will assure that the aperture **74** overlies the recess **52** in cradle **40**. Cradle **40** has four upwardly extending arms which have an interior surface that is shaped to complement the exterior diameter of the chamber **60**. Cradle **40** also has undercuts **50** which are adjacent to each arm **54**. Each undercut **50** is dimensioned to receive a projection **58** which projects

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inwardly from a free end of the clamp **56**. The clamps **56** are adjustable on the cradle **40** and include threaded bores **57**, see **Figures 4** and **5**, which receive set screws to tighten the chamber **60** against the cradle **40**.

In addition to the above structure, cradle **40** includes a dependant boss **42**. Boss **42** is dimensioned to fit within the aperture **30** of switch base **22**, see **Figure 5**. With reference to **Figure 7**, it can be seen that the cradle **40** includes a cam follower slot **46** at the reflector end **62**. At the opposite array end **64**, the cradle **40** includes an oblong slot **48**. The cam **45** and the cam fastener assembly **47** are illustrated in **Figure 7** as located in slot **46**; however, this is shown for illustrative purposes only and does not represent the actual structure. In the active switch assembly as shown in **Figure 5**, the cam **45** is within the slot **46** but, the fastener of assembly **47**, a cap screw, is actually passed through the aperture **38** in switch base **22**. This is done to provide access to the adjust cam **45** after the cradle **40** is positioned in the base **22**.

The below description of the assembly and alignment of the switch assembly will assume that both the input and output waveguides are aligned on a vertical axis and that one input waveguide is aligned with the center focal point of the reflector **5** on the Z axis. In the initial stages, the chamber **60** is assembled as shown in **Figure 6** with the reflector **5** fixed in the seat **82** and the waveguide array **9** having been preliminarily aligned and loosely secured with the fastener **68**. Next, the cradle **40** is placed in the switch base **22** so that the boss **42** rest in the aperture **30** and the pin **78** is free to move within the

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intersecting aperture **31**. Following this step, the refractive element carrier **24** with the refractive element **6** detached thereto is set in the recess **52** of the cradle **40** so that the projecting arm **25** is within the U-shaped cavity **35** of carrier support **32**. The jeweled pivot pins are inserted through the apertures **36** in switch base **22** and appropriate set screws are installed. A hex head fastener is passed through slot **48** into the threaded bore **39** of the switch base **22**. At the reflector end of the cradle **40**, the cam **45** is placed in the cam follower slot **46**, and a fastener assembly **47** is attached. The hex head fastener passes through aperture **38** in the switch base **22**, through the cam **45**, past the cradle **40** and is secured with a nut. As shown in **Figure 8**, the chamber **60** is illustratively attached by the clamps **56**. In actuality, the chamber **60** overlies the refractive element **6** as shown in **Figure 5**. After the assembly is completed, the initial position of the ~~reflective~~ refractive element carrier **24** is adjusted by the use of stops positioned in the stop apertures **33** of carrier **32**. This adjustment is accomplished in essentially the same manner as described in U.S. Patent 5,661,827. It should also be remembered at this time that the switch assembly **20** will include a coil **28** on either side of the magnets **26** in the refractive element carrier **24**. After the assembly is completed and the stops have been initially adjusted, there is a visual inspection made through viewer port **72** to see the initialization point of the refractive element **6**. The element **6** is adjusted by a circular motion which is achieved by movement of the boss **42** within the aperture **30**. This accomplishes a vertical alignment of the reflected signal with the waveguides **9**. This motion moves

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the reflected signal from left to right with respect to the vertical axis through the waveguides. When this initial adjustment is satisfactory, the chamber **60** may be rotated about its longitudinal axis as necessary.

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